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Proton-Proton Scattering below 20 MeV

By R. G. HERB*

Early Experiments

Proton scattering experiments first made unambiguous contributions to our understanding of the nature of the nucleon with the work of TUVE, HEYDENBURG, and HAFSTAD in 1936[1]. The experiment in principle is one of the simplest. Protons are accelerated to high energy by means of a machine such as a Van de Graaff generator, a cyclotron, or a transformer rectifier set. A collimated beam of high energy protons is directed onto a target of hydrogenous material or, more commonly, passes through hydrogen gas. Target thickness is chosen so that all but a few parts per million of the protons pass through the target with little change in direction and are collected in a cylindrical cup where the charge accumulated over an operating period is a measure of the number of protons that have passed through the target.

Protons that have close encounters with target nuclei may be scattered at large angles with respect to the incident beam axis. A detector system is provided to count the scattered protons in any selected angular region in order to determine the probability of scattering into this region.

If the target is a solid such as polyethylene, the detector system must be arranged to reject protons scattered by carbon nuclei or nuclei of other heavy elements. If the target is hydrogen gas, contributions from nuclei of impurity atoms can be made small and they can be monitored. Interference effects between the two protons of the hydrogen molecule appear to be negligible[2]. Effects of the two electrons of the molecule are small[3] and corrections need be made only for experiments of high accuracy. Effects of molecular motion are also negligible. Thus, to a good approximation, hydrogen gas at a pressure of 12 mm of mercury consists for the purposes of this experiment of independent stationary protons with a density of 8.4×10^{17} protons/cm^3. This is the hydrogen pressure used in the experiments of TUVE, HEYDENBURG, and HAFSTAD[1].

With hydrogen along the trajectory of the proton beam throughout the scattering chamber the target region is defined by an analyzing slit system as illustrated in Figure 1 while Figure 2 gives a view of the scattering chamber. High energy protons for this experiment were furnished by a Van de Graaff generator constructed by TUVE, HAFSTAD, and DAHL, operating in air at atmospheric pressure up to potentials of about 1 million volts. This was the first operational Van de Graaff accelerator. Generator voltage could be measured to an accuracy of about 2%. A reasonably steady proton current of about 0.02 μA passed through a thin aluminum foil at the entrance to the collimator where it was restricted by circular apertures ranging from a diameter of 2 mm at the entrance to 2.6 mm at the exit. The detector was an ionization chamber, separated from the hydrogen-filled region by a collodion foil. A pulse was produced by each scattered proton which was accepted by the analyzer slit system and passed into the ionization chamber.

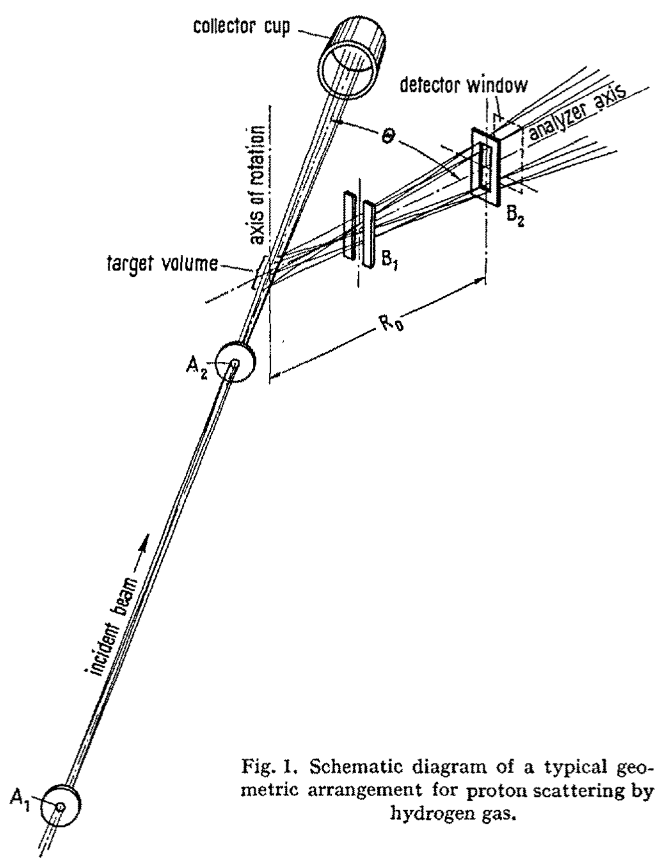

Fig. 1. Schematic diagram of a typical geometric arrangement for proton scattering by hydrogen gas.

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1 M. A. TUVE, N. P. HEYDENBURG, and L. R. HAFSTAD, Phys. Rev. *50*, 806 (1936).

2 Approximate calculations by J. L. POWELL, unpublished.

3 G. BREIT, Phys. Rev. Letters *1*, 200 (1958).

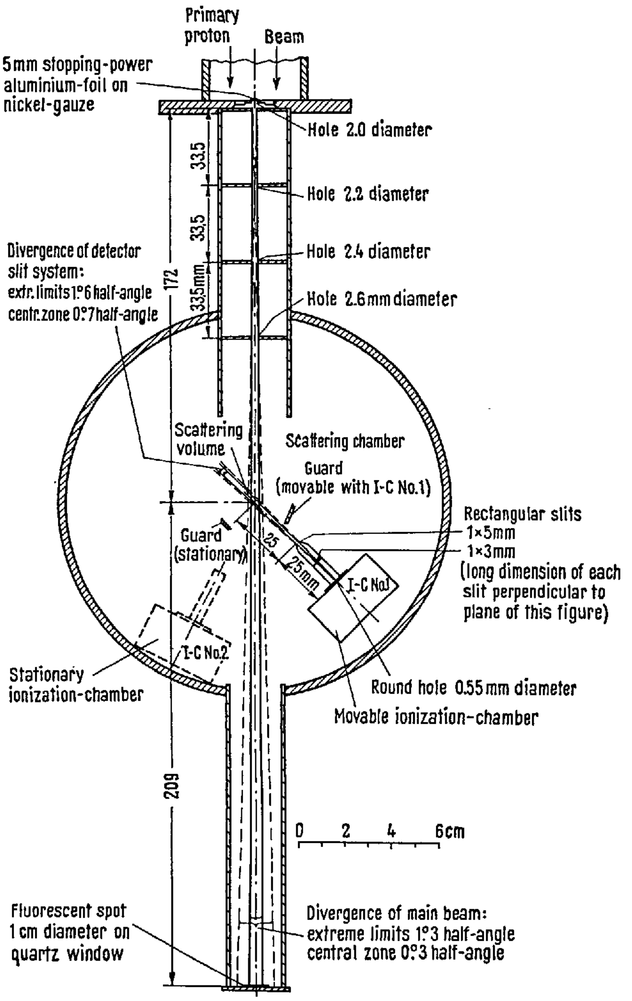

Fig. 2. Scattering chamber used by TUVE, HEYDENBURG, and HAFSTAD[1] in early experiments.

In their first paper, TUVE, HEYDENBURG, and HAFSTAD[1] reported measurements with incident protons having energies of 900, 800, 700, and 600 keV, scattered through angles from the incident beam of 15 degrees to 45 degrees. At each angle and energy a value was determined for the ratio of observed yield to the yield predicted by the Mott formula.

Interpretation

At large separation distances the force between two protons is due almost entirely to their electrical charge and this force is Coulombian except for a small correction due to vacuum polarization effects. Neglecting all but the Coulomb force, MOTT[4] computed the yield of protons scattered by protons as a function of angle and energy. Usually a departure from Coulomb scattering between protons is referred to as a departure from Mott scattering.

For separation distances comparable to nuclear dimensions other forces were to be expected between protons, and data on binding energies of nuclei and on nuclear energy levels permitted estimates of the characteristics of these forces.

Formulae developed by TAYLOR[5] and by MOTT and MASSEY[6] are presented by BREIT, CONDON, and PRESENT[7], for the scattering of protons by protons where forces at close distances depart from the Coulomb force. The incident beam of protons is represented by plane waves classified according to angular momenta. The protons making head-on collisions with target nuclei constitute the s-wave, those with one unit, $\hbar$, of angular momentum constitute the p-wave, those with two units ($2\,\hbar$) constitute the d-wave, etc. The amplitude of the outgoing waves, which when squared give yield contributions, are determined by the phase of the resultant of incoming and outgoing waves at some suitable chosen close-in boundary. As the phase difference between incident and resultant wave goes from 0 to 90°, the scattered intensity contributed goes from 0 to a maximum. Protons making head-on collisions will penetrate farthest through the Coulomb barrier at a given energy and thus we expect s-wave protons to first feel departures from the Coulomb force. P-wave protons might be expected to penetrate to the non-Coulombian regions at higher energies. For energies up to 20 MeV protons with more than 2 units of orbital angular momentum should not be expected to feel appreciably the non-Coulombian force.

In their classic paper on this subject BREIT, CONDON, and PRESENT[7] show that exploration of the force field between protons is reduced in the elastic scattering region to the problem of determining the s-wave, the p-wave, the d-wave, etc., phase shifts as a function of incident proton energy. They obtained a satisfactory fit to the data of TUVE, HEYDENBURG, and HAFSTAD utilizing only an s-wave distortion, or phase shift, by a non-Coulombian field. Any non-Coulombian p- or d-wave phase shift appeared to be small or perhaps zero. Thus protons of energies up to 900 keV were shown to penetrate appreciably into the inner non-Coulombian fields only if collisions are head-on.

A very thorough survey was then made by these authors of force fields that gave the observed s-wave phase shifts. The force was shown to be attractive and to be short range with little or no effect for distances beyond about 6×10^{-13} cm. Details of the variation of this force with distance could not be determined and thus the shape of the resulting potential well could not be established.

One potential well found to give a good fit to the data had sides of infinite slope, width 2.8×10^{-13} cm and depth 10.5 MeV. This is called a 'square well' and

[4] N. F. MOTT, Proc. Roy. Soc. *A 118*, 542 (1928).
[5] H. M. TAYLOR, Proc. Roy. Soc. *A 134*, 103 (1931); *A 136*, 605 (1932).
[6] N. F. MOTT and H. S. W. MASSEY, *The Theory of Atomic Collisions* (Oxford University Press).
[7] G. BREIT, E. U. CONDON, and R. D. PRESENT, Phys. Rev. *50*, 825 (1936).

has been widely used as a convenient approximation although it is recognized as highly artificial.

Other experiments had given information on the interaction between a neutron and a proton in the singlet s state (the state of zero angular momentum and with spins antiparallel) and BREIT, CONDON, and PRESENT[7] concluded that this interaction between neutron and proton is very nearly equal to that between two protons, neglecting the Coulomb force between protons.

Extension of Experimental Work through 1941

With the success of the method amply demonstrated for investigation of the nature and characteristics of nucleons a succession of experiments were carried through. HAFSTAD, HEYDENBURG, and TUVE[8,9] made measurements at proton energies down to 450 keV and later with new improved apparatus repeated their previous measurements over the energy region up to 900 keV. Some of their data are shown in Figure 3a and 3b where the ratios of observed scattering yield values to computed Mott yield values are plotted.

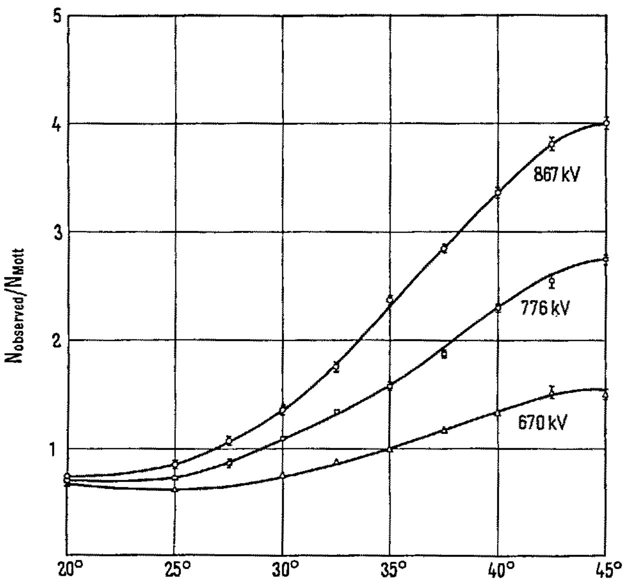

Fig. 3a

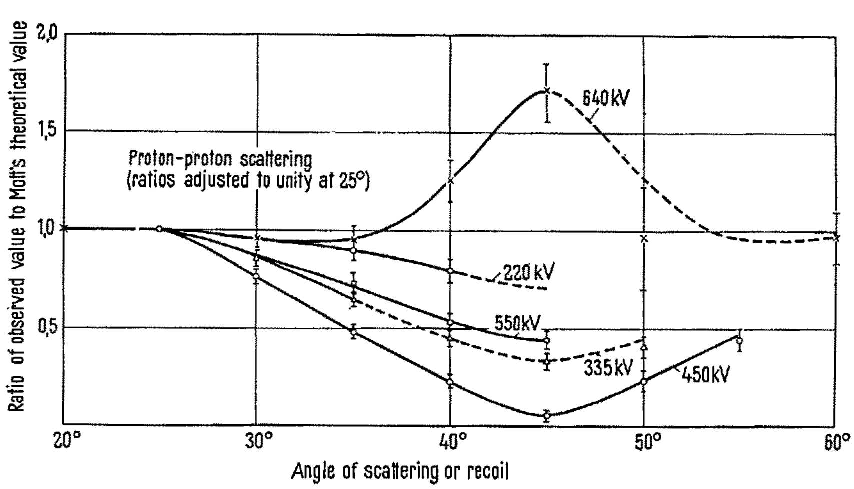

Fig. 3b

Fig. 3a, 3b. Measurements of HAFSTAD, HEYDENBURG, and TUVE[8] showing departures from Coulombian scattering. Interference between the repulsive Coulomb force and an attractive nuclear force causes the low yield at 45° for proton energies near 400 keV.

At Wisconsin HERB, KERST, PARKINSON, and PLAIN[10] made measurements extending from 860 keV to approximately 2.4 MeV and RAGAN, KANNE, and TASCHEK[11] investigated the energy region from 200 keV to 300 keV. Values of the s-wave phase shift were now available at closely spaced energies up to 2.4 MeV. Where values for different groups overlapped, agreement was good. A square well of 2.8×10^{-13} cm width and 10.5 MeV depth fit all data satisfactorily. Details of the shape of the potential well were still not extablished but the variety of potential shapes permitted was now more restricted. Evidence for non-Coulombian contributions due to protons having one or more units of angular momentum (p, d, etc. waves) was still inconclusive. Within the accuracy of the data only protons making head-on collisions penetrated to where appreciable departures from Coulomb forces are felt.

Experimental Contributions since 1950

During the past decade a great many proton-proton scattering experiments have been carried out over a wide range of energies. Only a few of these can be mentioned in this short review. WORTHINGTON, MCGRUER, and FINDLEY[12] developed techniques which gave values that appeared to be accurate to a few

[8] L. R. HAFSTAD, N. P. HEYDENBURG, and M. A. TUVE, Phys. Rev. *53*, 239 (1938).

[9] N. P. HEYDENBURG, L. R. HAFSTAD, and M. A. TUVE, Phys. Rev. *56*, 1078 (1939).

[10] R. G. HERB, D. W. KERST, D. B. PARKINSON, and G. J. PLAIN, Phys. Rev. *55*, 998 (1939).

[11] G. L. RAGAN, W. R. KANNE, and R. F. TASCHEK, Phys. Rev. *60*, 628 (1941).

[12] H. R. WORTHINGTON, J. N. MCGRUER, and D. E. FINDLEY, Phys. Rev. *90*, 899 (1953).

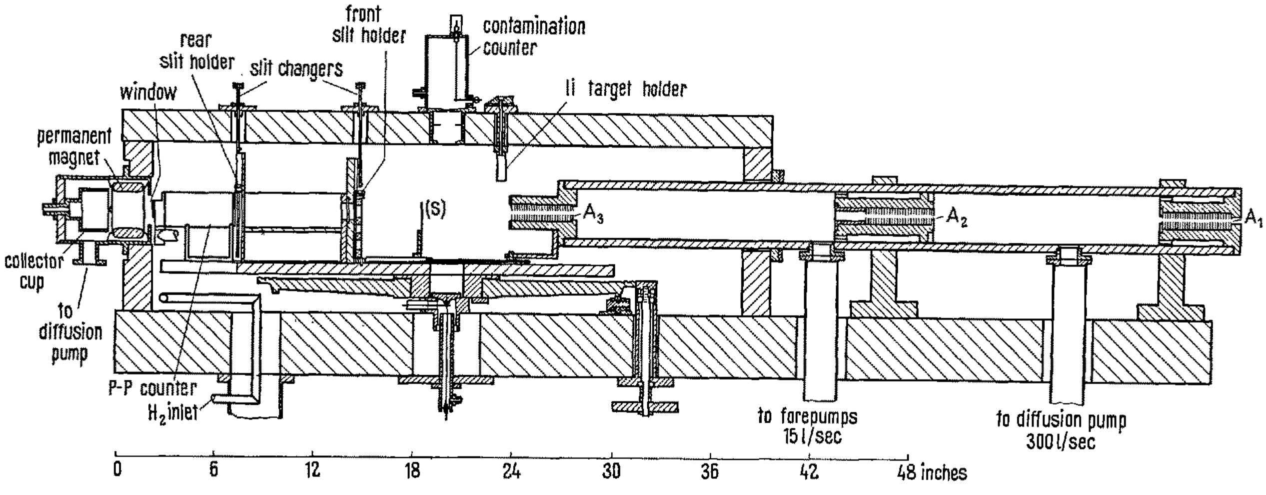

Fig. 4a

tenths of 1%. Their scattering chamber is shown in Figure 4a and 4b. Measurements from 1.8 MeV to 4.2 MeV were analyzed by HALL and POWELL[13] and inclusion of small p-wave contributions improved the agreement with measurement over that given by pure s-waves. Later developments have cast some doubt on this interpretation.

YNTEMA and WHITE[14], utilizing 18 MeV protons from a cyclotron and solid targets of polyethylene, polystyrene, and nylon, obtained scattering yields as a function of angle with accuracies that appeared to be about 1%. At this energy non-Coulombian forces might be expected for protons with one or two units of angular momentum. Their best fits gave small p- and d-wave effects. Other measurements of particular importance in the energy region below 20 MeV are those of JOHNSTON and YOUNG[15] at 10 MeV. COOPER, FRISCH, and ZIMMERMAN[16] made measurements in the region from 350 keV to 420 keV. They made use of interference between the repulsive Coulomb force and the attractive nuclear force and found that 45° scattering went to a minimum at 383.9 keV. From this result a value was determined for the s-wave phase shift at this energy.

Recent Theoretical Analyses

Theoretical analysis of proton scattering results in the low energy region have been greatly influenced by results of a large number of experiments at energies extending up to the BeV region where incident protons with many units of angular momentum feel the non-Coulombian force. Phase shift analyses have in no case given unique values and thus information on the force field between protons has continued to be ambiguous.

HULL and SHAPIRO[17], utilizing a high speed digital computer, demonstrated that even in the low energy region where data are relatively accurate and angular momenta beyond $2\hbar$ are not expected, unique solutions are not in general obtained. Incident p-wave (or other odd momenta) protons have spins parallel to spins of target protons. Spin and orbital angular momenta for incident p-wave protons can therefore give a resultant angular momentum of zero, $\hbar$, or $2\hbar$, and interactions may not be the same for these three values. Thus the number of parameters is great, and demands that must be met by the experimentalists to provide unique solutions are severe. The analyses of HULL and SHAPIRO[17], of MACGREGOR[18], of HELLER[19], and others show that the most accurate data available can be fitted with a variety of p- and d-wave contributions.

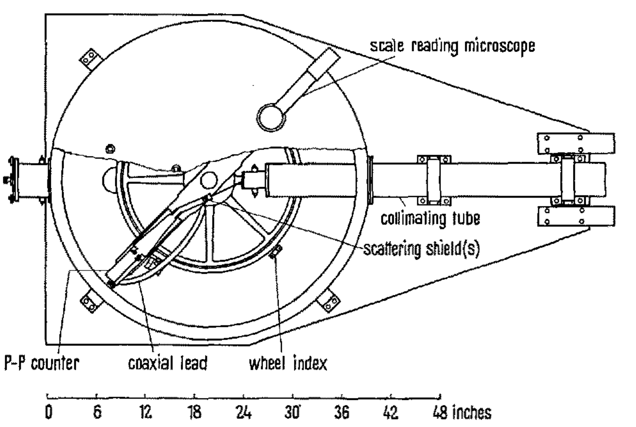

Fig. 4b

Fig. 4a, 4b. Two views of the scattering chamber used by WORTHINGTON, MCGRUER, and FINDLEY[12], and by KNECHT, MESSELT, BERNERS, and NORTHCLIFFE[25]. Hydrogen flows continuously into the chamber and flows out through the high impedance regions near A_3, A_2, and A_1.

[13] H. H. HALL and J. L. POWELL, Phys. Rev. *90*, 912 (1953).
[14] J. L. YNTEMA and M. G. WHITE, Phys. Rev. *95*, 1226 (1954).
[15] L. H. JOHNSTON and D. E. YOUNG, Phys. Rev. *116*, 989 (1959).
[16] D. I. COOPER, D.-H. FRISCH, and R. L. ZIMMERMAN, Phys. Rev. *94*, 1209 (1954).
[17] M. H. HULL, jr., and J. SHAPIRO, Phys. Rev. *109*, 846 (1958).
[18] M. H. MACGREGOR, Phys. Rev. *113*, 1559 (1959).
[19] L. HELLER, Phys. Rev. *120*, 627 (1960).

It is generally agreed that polarization data are needed. In all experiments discussed above, spins of incident protons were randomly oriented and spins of target nuclei were also randomly oriented. Additional information may be obtained on contributions from waves of odd orbital momentum if spins of incident or target protons are oriented preferably in one direction. These experiments are difficult in the low energy region but results of value have already been obtained[20,21]. More extensive results can be expected within the next few years. Polarization measurements will undoubtedly be of great help in restricting the choice of phase shifts that give satisfactory fits to data. Experiments of higher accuracy without spin orientation should also be of value and may well be necessary for a unique determination of the interaction fields between protons. In the next section some recent advances in accuracy and possibilities for further progress will be discussed.

Progress and Possibilities in Accuracy of Measurements

FOLDY and ERIKSEN[22] first showed that vacuum polarization may make appreciable contribution in proton-proton scattering. DURAND[23] extended these computations and showed that contributions extend to very high orbital angular momentum values. DURAND also gives relativistic corrections of importance for data of high accuracy. Computations by SILVERSTEIN[24] on geometric factors of gas scattering chambers (effective solid angle of detection and effective target thickness) showed that previous calculations had not been sufficiently accurate for the newer experiments.

KNECHT, MESSELT, BERNERS, and NORTHCLIFFE[25] made measurements at 1.8 MeV with the apparatus of Figure 4 and were unable to fit their data satisfactorily with a reasonable choice of phase shifts until the vacuum polarization and relativistic corrections of DURAND[23] were applied. Results finally obtained by KNECHT, MESSELT, BERNERS, and NORTHCLIFFE[25] set very low limits on p- and d-wave contributions and appeared to establish an s-wave phase shift with high accuracy.

Some of the requirements to be met for extension of accuracy over the energy region below 20 MeV will now be discussed.

The Accelerator. A compact beam of protons, highly monochromatic in energy, with accurately known energy and with low angular divergence is clearly advantageous. Either a transformer rectifier set or a Van de Graaff generator can satisfy these requirements. Van de Graaff generators utilizing hydrogen negative ions may soon be available for energies up to about 20 MeV.

Beam Collimation. In the work of WORTHINGTON, MCGRUER, and FINDLEY[12] and of KNECHT, MESSELT, BERNERS, and NORTHCLIFFE[25] the proton beam passes through two circular apertures of $1\text{–}^1/_2$ mm diameter, spaced 1 m apart. A series of diaphragms with larger holes contribute to impedance for gas flow. Protons impinging on the edges of apertures A 3 and A 1 (of Fig. 4 a) may after some energy loss be scattered out of the metal and a small percentage of these protons will be scattered into the beam. Four MeV protons may enter the beam after impinging on a steel diaphragm as far as 0.05 mm out from the edge. If the aperture holes are shrunk to smaller diameters, the beam is more accurately fixed in angle and in position, but a larger fraction of the protons are degraded in energy.

Low energy protons in the beam may cause large errors at small scattering angles. From these considerations, but without the benefit of accurate calculations, a high Z material was used for the defining apertures of the collimator used by KNECHT et al.[25]. A large proportion of the protons scattered out are thereby scattered through large angles and do not appear in the beam.

KNECHT et al.[25] found that asymmetries introduced as the beam shifts in the collimator produce errors in small angle cross section measurements. Results were much improved when a pair of pickup plates were installed in the collector cup to detect beam asymmetry in the plane of the scattering chamber. Error signals fed to a small deflecting magnet just beyond the first aperture (A 1 of Fig. 4 a) maintained the beam accurately in a vertical plane passing through the collimator axis. Improvement of beam centering in the collimator should decrease the proportion of low energy protons scattered from aperture edges. Complete automatic positioning of the beam in the collimator may be a requirement for measurements of high accuracy.

Analyzer Apertures. Apertures B 1 and B 2 of Figure 1 determine effective target thickness and effective solid angle subtended by the detector. Some of the protons hitting the edges of these apertures will not be stopped in the materials but will be scattered out, and a certain percentage of those scattered out will reach the detector. The effective width of B 1 and the effective area of B 2 are therefore greater than the measured values. COURANT[26] developed formulae for computing these effects and he computed corrections for the slit systems used in the experiments of YNTEMA and WHITE[14] (see Fig. 5). NORTHCLIFFE[27], utilizing COURANT's expressions, made extensive calculations of corrections to be applied in the work of KNECHT, MESSELT, BERNERS, and NORTHCLIFFE[25]. The computations were difficult and their accuracy was hard to assess. NORTHCLIFFE[27]

[20] K. W. BROCKMAN, jr., Phys. Rev. *110*, 163 (1958).
[21] I. ALEXEFF and W. HAEBERLI, Nuclear Phys. *15*, 609 (1960).
[22] L. L. FOLDY and E. ERIKSEN, Phys. Rev. *98*, 775 (1955).
[23] L. DURAND III, Phys. Rev. *108*, 1597 (1957).
[24] E. A. SILVERSTEIN, Nuclear Instr. *4*, 53 (1959).
[25] D. J. KNECHT, S. MESSELT, E. D. BERNERS, and L. C. NORTHCLIFFE, Phys. Rev. *114*, 550 (1959).
[26] E. D. COURANT, Rev. Sci. Instr. *22*, 1003 (1951).
[27] L. C. NORTHCLIFFE, Ph. D. Thesis, University of Wisconsin (1957).

found that the magnitude of slit edge contributions depends in a complicated way on the atomic number of the material and on the density of the material. Stellite, which had been used in the experiment, was found to be one of the better materials to form aperture B2. These calculations indicated that beryllium would have been considerably better than stellite to form the aperture B1. Beryllium slits were made up by the Argonne Laboratory but as yet have not been used. BECKER[28] made more extensive Monte Carlo calculations using a digital computor. According to these calculations, beryllium may not be appreciably better than the stellite that had been used.

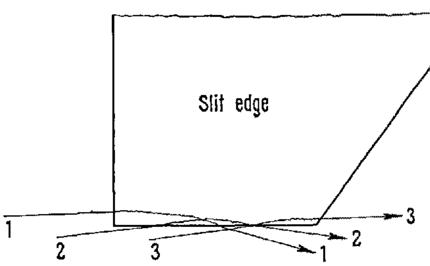

Fig. 5. Showing how protons after undergoing several scatterings in a slit edge may re-enter a beam or may pass through to a detector. In COURANT's[26] analysis protons were divided into the three classes illustrated in this Figure.

Corrections can be made for slit edge scattering if the detector gives an accurate measure of proton energies. In the experiments of WORTHINGTON, MCGRUER, and FINDLEY[12] and in the later experiments of KNECHT, MESSELT, BERNERS, and NORTHCLIFFE[25] corrections were based to a considerable extent on analysis of pulse heights from the proportional counter used in the experiments.

Slit edge scattering contributed substantially to the uncertainties in the experiments referred to above. They constitute perhaps the most difficult of the problems to be faced in experiments of higher accuracy.

The Detector. A detector to be satisfactory for precise experiments in proton-proton scattering must have an efficiency very close to 100%. A proportional counter meets this requirement satisfactorily if carefully designed. A proportional counter, however, does suffer from a number of disadvantages. The window separating the counter chamber from the scattering chamber must meet very stringent requirements. It must be thin to avoid great energy loss and it must be capable of withstanding a substantial pressure difference without breakage, gas leakage, or diffusion. A material of low atomic number is advantageous to hold large angle scattering to acceptable values. All characteristics of the counter must be very carefully studied as a function of type of gas, gas pressure, and voltage. A large counter volume filled with a heavy gas at high pressure is needed to completely stop protons having energies of a few MeV. These requirements are not compatible with the need for fast electron collection and uniformity of pulse height for a given proton energy. It is therefore necessary to use relatively low pressure gas so that protons having energies of a few MeV lose only a fraction of this energy in passing through the counter. Energy analysis is possible under these conditions but it is difficult.

The scintillation detector now appears to be satisfactory for protons of 5 MeV and above, and for lower energy protons the new biased junction detectors show promise. If they prove to be satisfactory the proton scattering problem will be greatly simplified.

Other Measurements and Corrections. Other measurements to be made such as hydrogen pressure and temperature, the effective target thickness, and the effective solid angle of the detector can be determined with care to one or two hundredths of 1%. The integration of beam current and measurement of the total charge collected during a given operational period present problems of some difficulty. Perhaps the most serious of these problems is the measurement of the capacitance of the condenser used for charge storage. Condensers utilizing polystyrene as a dielectric have been almost universally used in recent experiments because of their low polarization (soak-in) characteristics, and low leakage. The measurement of condenser capacitance to an accuracy of 0.05% or better requires a great deal of difficult and painstaking work. Also to be faced is the problem of possible change in capacitance with changes in temperature, in barometric pressures, or with any small distortion of the condenser case caused by handling.

Concluding Remarks

A sense of disappointment may be felt in considering the immense amount of experimental work and theoretical analysis that have been concentrated onto the problem of proton-proton scattering with results giving only a very qualitative understanding of the nucleon-nucleon interactions. We should, however, consider that the nucleons which two decades ago were thought of as simple elementary particles now appear to be taking on characteristics and structure of great complexity. Perhaps the interactions of highly complex particles should not be expected to be simple and to yield easily to measurements.

We can safely conclude that all proton-proton scattering measurements must be repeated with higher accuracy. Because of technical advances, difficulties expected in measurements accurate to 1 or 2 tenths of 1% should not be appreciably greater than those encountered a decade or two ago for measurements accurate to 1 or 2%.

[28] R. L. BECKER, Ph. D. Thesis, Yale University (1957).

Zusammenfassung. Die Resultate der älteren Proton-Proton-Streuexperimente konnten durch die Annahme erklärt werden, dass Protonen, die einen Zentralstoss erleiden, sich bei Annäherung auf etwa 3×10^{-13} cm stark anziehen. Die Form des entsprechenden Potentialtopfes konnte nicht festgelegt werden. Auf Grund späterer Experimente konnte die zulässige Form des Potentials begrenzt, aber nicht eindeutig bestimmt werden.

Für Protonen mit höherem Bahndrehimpuls zeigen sich unterhalb 20 MeV nur kleine Abweichungen von der Rutherfordschen Streuung, und nur wenig ist bekannt über die Natur der Wechselwirkung.

Die experimentellen Probleme, welche der weiteren Verbesserung der Messgenauigkeit im Wege stehen, werden diskutiert.

Chemie und Stoffwechsel der Polyenfettsäuren *

Von E. KLENK**

Für das Problem, auf welches im folgenden näher eingegangen werden soll, sind zwei schon längere Zeit zurückliegende Entdeckungen von besonderer Bedeutung. Es handelt sich einerseits um die Auffindung einer C_{20}-Tetraensäure in den Leberphosphatiden durch HARTLEY[1], und andererseits um den wohlbekannten Befund von BURR und BURR[2] über die essentielle Natur der im Nahrungsfett vorkommenden Polyensäuren von der Art der Linol- und Linolensäure.

Die C_{20}-Tetraensäure, die später den Namen Arachidonsäure erhielt, erwies sich als regelmässiger Baustein der Phosphatide der Leber und anderer Organe. Sie besitzt ebenfalls die Eigenschaften einer essentiellen Fettsäure[3]. Ihre biologische Wirksamkeit übertrifft die der Linolsäure um ein mehrfaches. Nach SMEDLEY-MACLEAN[4] ist die Arachidonsäure $\Delta^{5,8,11,14}$-Eicosatetraensäure. Von der endständigen Methylgruppe aus gerechnet befinden sich die ersten beiden Doppelbindungen an derselben Stelle wie in der Linolsäure. Wegen dieser Ähnlichkeit der chemischen Konstitution hat auch SMEDLEY-MACLEAN bereits angenommen, dass die Arachidonsäure im Tierkörper aus exogen zugeführter Linolsäure durch Kettenverlängerung und Dehydrierung entsteht. Der exakte Beweis dafür wurde erst viele Jahre später von MEAD et al.[5] mit Hilfe der Tracermethode erbracht.

Im Anfang der dreissiger Jahre hatten wir[6] gefunden, dass in den Organphosphatiden ausser den C_{20}-Polyensäuren von der Art der Arachidonsäure auch regelmässig noch C_{22}-Polyensäuren vorkommen und dass diese letzteren noch stärker ungesättigt sind als die Arachidonsäure. Sie gleichen ihrem Verhalten nach der Clupanodonsäure der Fischöle, die damals als eine Docosapentaensäure angesprochen wurde. Es war offensichtlich, dass die C_{20}- und C_{22}-Polyensäuren der Organphosphatide der Säugetiere und die Polyensäuren der Fischöle in naher Beziehung zueinander stehen mussten.

Nach einer über zehnjährigen Unterbrechung, bedingt durch die Kriegsereignisse, konnten diese Untersuchungen erst im Jahre 1950 wieder aufgenommen werden. Als besonders wertvoll für alle weiteren Versuche auf diesem Gebiet erwies sich eine von uns[7] ausgearbeitete Methode des oxydativen Ozonidabbaus der Polyensäuren und der quantitativen chromatographischen Bestimmung der dabei auftretenden Abbaudicarbonsäuren. Nimmt man als Beispiel die Arachidonsäure (siehe die Konstitutionsformel), so führt theoretisch der oxydative Abbau zu einem Mol Glutarsäure und drei Mol Malonsäure/Mol Polyensäure. Bei den bisherigen Abbaumethoden tritt Malonsäure nicht oder nur spurenweise auf, zu fassen sind nur die höheren Dicarbonsäuren. Mit der neuen Methode erhält man Malonsäure in reichlichen Mengen, in der Regel 50% der Theorie, die höheren Dicarbonsäuren jedoch in nahezu quantitativer Ausbeute. Diese Methode ermöglicht es auch, die Dicarbonsäuren, die vom Carboxylende stammen, und diejenigen, die aus der Mitte der Kohlenstoffkette herausgespalten werden, zu unterscheiden. Wird nämlich der Abbau mit dem Ester

* Nach einem Vortrag auf der gemeinsamen Tagung der deutschen, französischen und schweizerischen Biochemiker in Zürich vom 10.–12. Oktober 1960.

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1 T. HARTLEY, J. Physiol. *38*, 353 (1909).

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3 O. TURPEINEN, J. Nutrition *15*, 351 (1938).

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